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# A scaling down mapping of *Pinna nobilis* (Linnaeus, 1758) through the combination of scientific literature, NATURA 2000, grey literature and citizen science data

Vanessa Marrocco[1], Francesco Zangaro[1], Alessandro Sicuro[1], Maurizio Pinna[1]

1 *Department of Biological and Environmental Sciences and Technologies, University of Salento, S.P. Lecce-Monteroni – 73100 Lecce, Italy*

Corresponding author: *Maurizio Pinna* (maurizio.pinna@unisalento.it)

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## Abstract

This research investigates the occurrence of *Pinna nobilis* (Linnaeus, 1758) in the Mediterranean Sea, where it is an endemic and the largest bivalve species. Such a species is protected under the European Council Directive 92/43/EEC since 1992, being exposed to anthropogenic impacts. The distribution of this species has been known, in the past, only from reports in scientific literature. Presently, the concerns, threats and risks for *P. nobilis* are increasing and a more detailed mapping of the actual distribution from a largest to a local spatial scale is essential for the implementation of monitoring, management and conservation actions. Here we provide a systematic review on the occurrence of *P. nobilis*, employing and combining different sources of information, such as scientific and grey literature, NATURA 2000 geodata and citizen science records. The methodological approach is a pilot test based on a scaling down of the geographical area of study, from the whole of the Mediterranean Sea to the Italian and Apulian coastline (South-East Italy); accordingly, the above mentioned sources of data have been gradually included. The results show that the combination of multiple sources of information provide a more exact determination of the species distribution at a local scale, identifying sites where in-depth actions are required to ensure the species conservation and restoration. Also, the IUCN has recently underlined that the conservation of *P. nobilis* has become a difficult challenge, so that each of the spatial scales for the investigation is crucial to enable a better preservation and conservation of the species in the Mediterranean Sea.

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**Keywords**
Pen shell, endangered species, Mediterranean Sea endemism, geographical scaling down, conservation and restocking

## Introduction

The fan mussel *Pinna nobilis* (Linnaeus, 1758) is the largest endemic bivalve of the Mediterranean Sea. Specimens grow up to 120 cm in total shell length (Zavodnik et al. 1991). It is a long-lived species reaching up to 45–50 years old (Richardson et al. 1999, Katsanevakis 2005, Galinou-Mitsoudi et al. 2006, Rouanet et al. 2015). *P. nobilis* occurs in soft-bottom habitats of transitional water ecosystems and in marine coastal zones at depths between 0.5 and 60 m, mostly in seagrass meadows of *Posidonia oceanica* or *Cymodocea nodosa* (Zavodnik et al. 1991, Richardson et al. 1999, García-March et al. 2007, Orfanidis et al. 2007, Coppa et al. 2010; 2013, Prado et al. 2014), but also in bare sandy bottoms (Katsanevakis 2005). The fan mussel lives with around 35% of its shell length buried in the bottom and the shell is attached to the substratum by a ropey texture called *byssus* (Papaconstantinou et al. 2007).

The species *P. nobilis* is an important benthic filter feeder contributing to water clarity (Davenport et al. 2011, Trigos et al. 2014, Alomar et al. 2015). Furthermore, a stable isotopes analysis (SIA) has demonstrated the response of *P. nobilis* to environmental and anthropogenic variables. There is scientific evidence that this species is a good indicator of changes in marine ecosystems providing information on biotic response to anthropogenic pressures (Alomar et al. 2015). *P. nobilis* supplies some ecosystem services by retaining a large amount of organic matter from the water column, hosting other species, working as a hard substrate in the soft-bottom seafloor, providing a surface that can be colonized by other benthic species, improving the local biodiversity (Basso et al. 2015), and attracting scuba-divers (e.g. tourism and recreation) (Marrocco et al. 2018).

During the 20$^{th}$ century, *P. nobilis* populations have greatly declined due to anthropogenic activities, including recreational and commercial fishing, ornamental harvesting, and accidental killing by anchoring, bottom nets and trawlers (Richardson et al. 2004).

Threatened by human activities and parasites, nowadays *P. nobilis* is a protected species under the Annex IV of EU Habitats Directive 92/43/EEC (EEC 1992) and Annex II of Barcelona Convention. Due to its ecological relevance, *P. nobilis* has recently been suggested as being a reliable bioindicator for benthic coastal ecosystems according to the Descriptor 1 "*Biological diversity*" and 4 "*Status of the single structural components of ecosystems*" of the EU Marine Strategy Framework Directive (MSFD 2008/56/EC), useful to achieve the Good Environmental Status (GES) by year 2020 (Vázquez-Luis et al. 2017a, Marrocco et al. 2018).

According to Basso et al. (2015), currently gaps in the knowledge of the species occurrence and behavior preclude the formulation of effective conservation strategies for *P. nobilis*. Studies on distribution and conservation status of this endangered species should be evaluated in different habitats, in different regions of the Mediterranean Sea and on

different time scales (e.g., long-term studies) to identify probable, common, or peculiar sources of mortality within the Mediterranean Sea (Basso et al. 2015). For this reason, here we provide a systematic review on the occurrence of *P. nobilis*, using and combining different sources of information such as scientific and grey literature, NATURA 2000 geodata and citizen science records. NATURA 2000 Network was established by the European Union to safeguard all the sites characterized by threatened environments and habitats as well as rare plants and animal species. It represents an official source of data about protected species and habitats in the EU. It is also a model of innovative conservation, which sees the integration of needs for protection with the economic, social and cultural needs of local populations (Genovesi et al. 2014). The methodological approach is based on a pilot test consisting of a gradual scaling down of the geographical area of study, from the whole Mediterranean Sea to Italy and, finally, to the Apulian coastline (South-East Italy). Along with such geographical decrease, the sources of data have been increased to reach a more detailed mapping of the species on a local scale. The objectives of the research are essentially the integration and combination of different sources of data about the distribution of *P. nobilis*. Currently, each source of data is characterized by gaps. We assume that the description of the occurrence of *P. nobilis* could be under-estimated when the data from scientific literature and NATURA 2000 Network are the unique source of information taken into account. To avoid or to bridge these gaps, we sustain that the actual distribution of *P. nobilis* can be determined by integrating different sources of data, including those from grey literature and citizen science, in a comprehensive map.

## Materials and methods

Scientific literature about *P. nobilis* has been retrieved from multiple databases related to cross-disciplinary research, which allow an in-depth exploration of specialized subfields within a certain academic or scientific discipline, such as Web of Science (http://www.webofknowledge.com/), Science Direct (http://www.sciencedirect.com) and Google Scholar (http://scholar.google.com). Scientific literature until September 2018 was selected; according to Basso et al. (2015), different combinations of the keywords "*Pinna nobilis*", "pen shell" and "fan mussel" were used.

Scientific literature data were mapped at the Mediterranean Sea scale. In this research we retrieved data published in peer-reviewed scientific journals as this is believed to ensure data reliability throughout the review process before publication.

The implementation of the Mediterranean Sea scale was done by consulting NATURA 2000 Standard Data Forms and Network Viewer (http://natura2000.eea.europa.eu/), typing "*Pinna nobilis*" as keyword. Within this analysis, we also considered data from grey literature and citizen science records when scaling down the geographical area to Italy, and lastly to the Apulian coastline.

The search for grey literature was introduced exclusively at a national scale with regard to Italy and was conducted by typing the same keywords used during the scientific literature search in the most common web search engines.

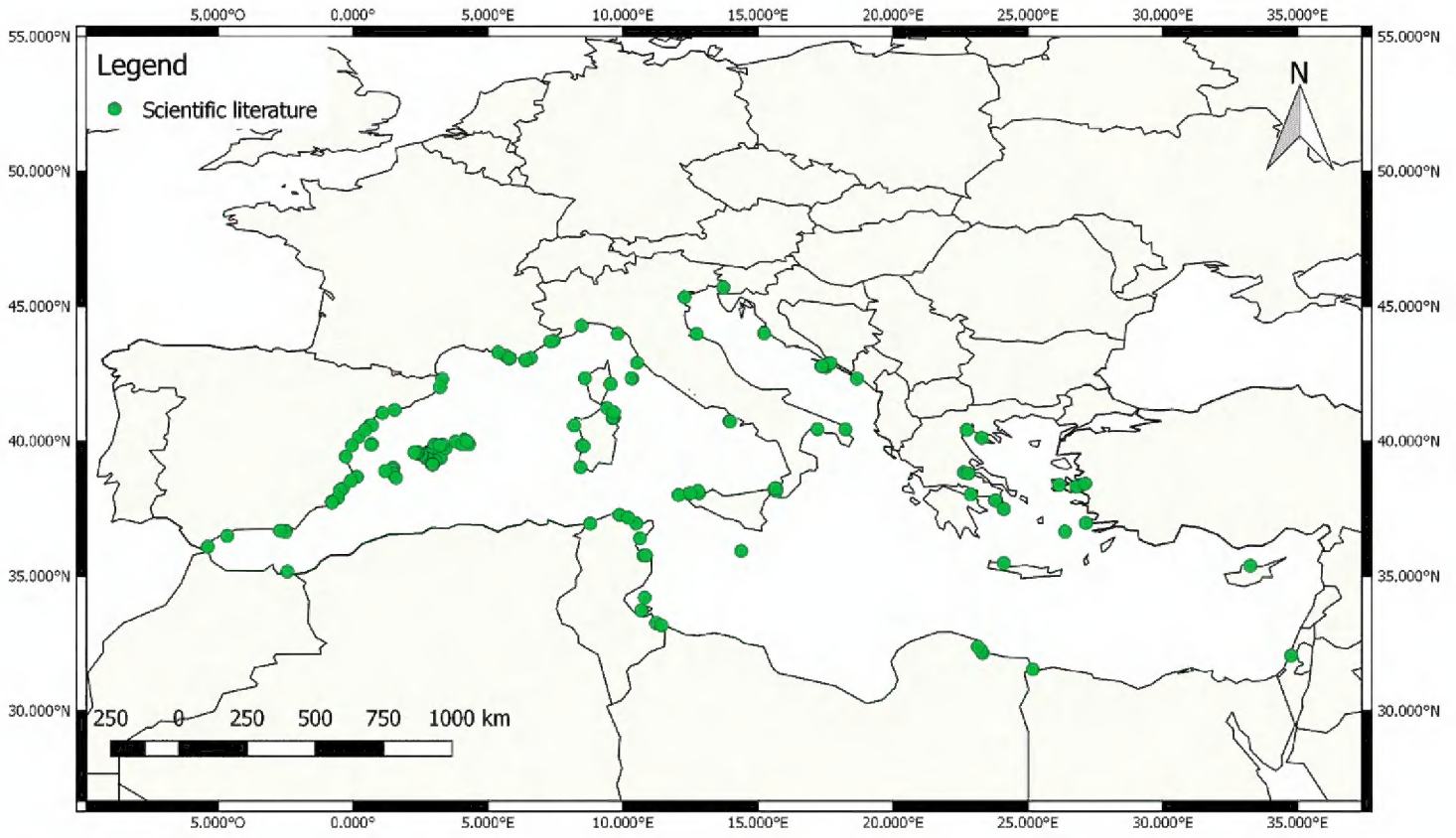


**Figure 1.** Map of *Pinna nobilis* distribution in the Mediterranean Sea based on scientific literature.

For what concerns the citizen science data, we focused on the Apulian coastline (South-East Italy). We collected information on the sightings of *P. nobilis* by personal communications and through direct interviews with fishermen, divers, tourists and staff from the local marine protected areas. About 100 people were interviewed during this process, but only the sightings that could certify the presence of the species through photos and videos, were taken into consideration. When possible, the sightings on those filed were verified by ourselves.

Using the data extracted, we drew five maps using the QGIS software, so as to identify possible patterns of the spatial distribution of *P. nobilis*.

The first map (Fig.1) was built considering all the scientific references obtained through the above-mentioned web channels. The second map (Fig. 2) shows data from NATURA 2000 Network Viewer integrated to those from scientific literature. The third map (Fig.3) further enriches the knowledge of the fan mussel distribution using data from grey literature, such as newspaper and journal articles, technical reports and theses. The fourth map (Fig. 4) focuses on the Apulian (South-East Italy) coastline, where we could access citizen science. By analyzing the data of such maps, we build a further map (Fig. 5) showing the occurrence of the fan mussel populations in the Mediterranean Sea.

## Results

The database obtained contains data until September 2018 and consists of a total of 187 scientific references, 398 points from NATURE 2000 Network Viewer, 63 points from grey literature and 8 citizen science records.

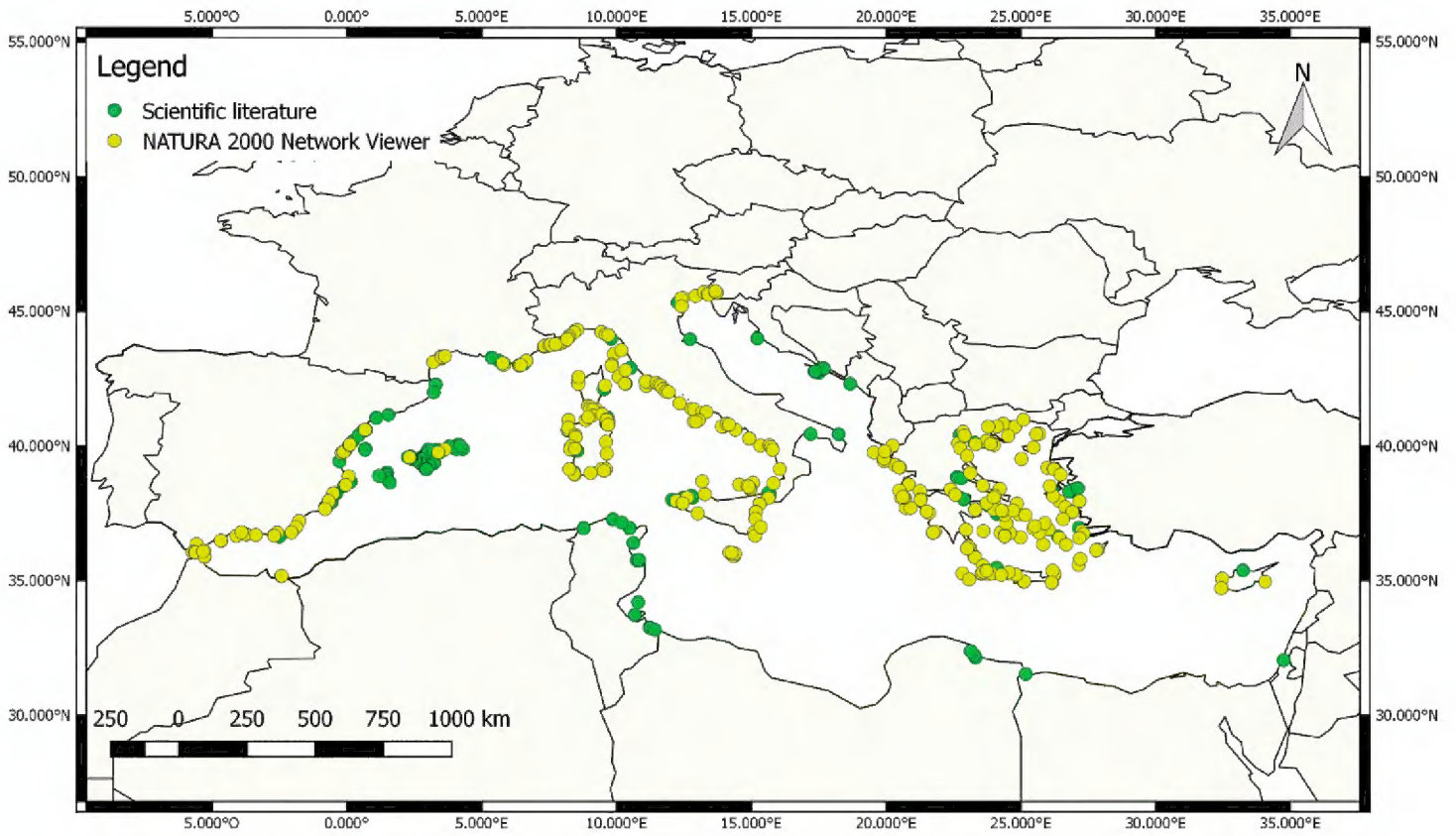


**Figure 2.** Map of *Pinna nobilis* distribution in the Mediterranean Sea based on scientific literature and NATURA 2000 Network Viewer geodata.

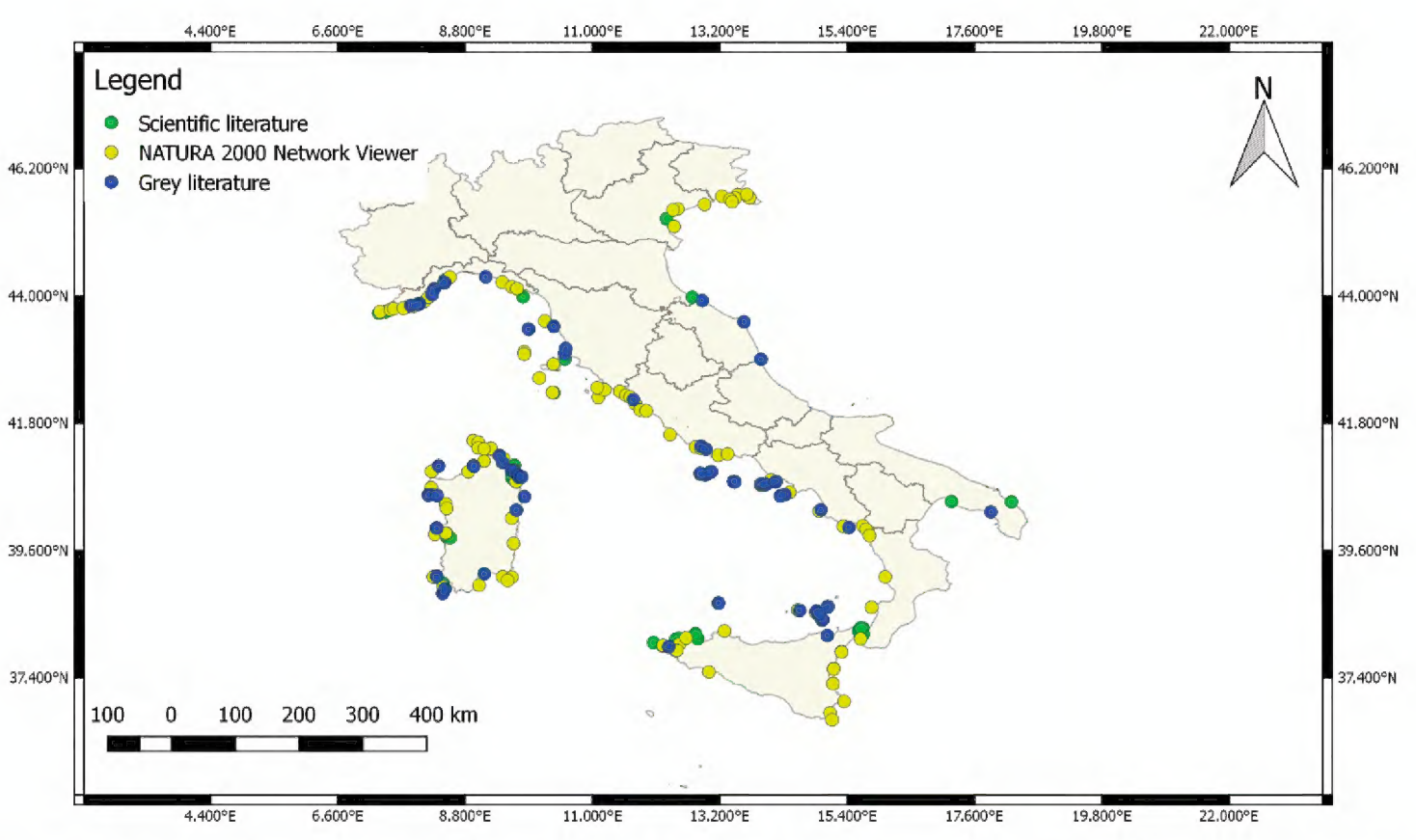


**Figure 3.** Map of *Pinna nobilis* distribution along the Italian coasts based on scientific literature, NATURA 2000 Network Viewer geodata and grey literature.

Considering the actual knowledge of the fan mussel distribution, based on all the scientific literature available until 2018 at the Mediterranean Sea scale, 187 records were mapped. In the scientific literature the species is mostly reported in the North-

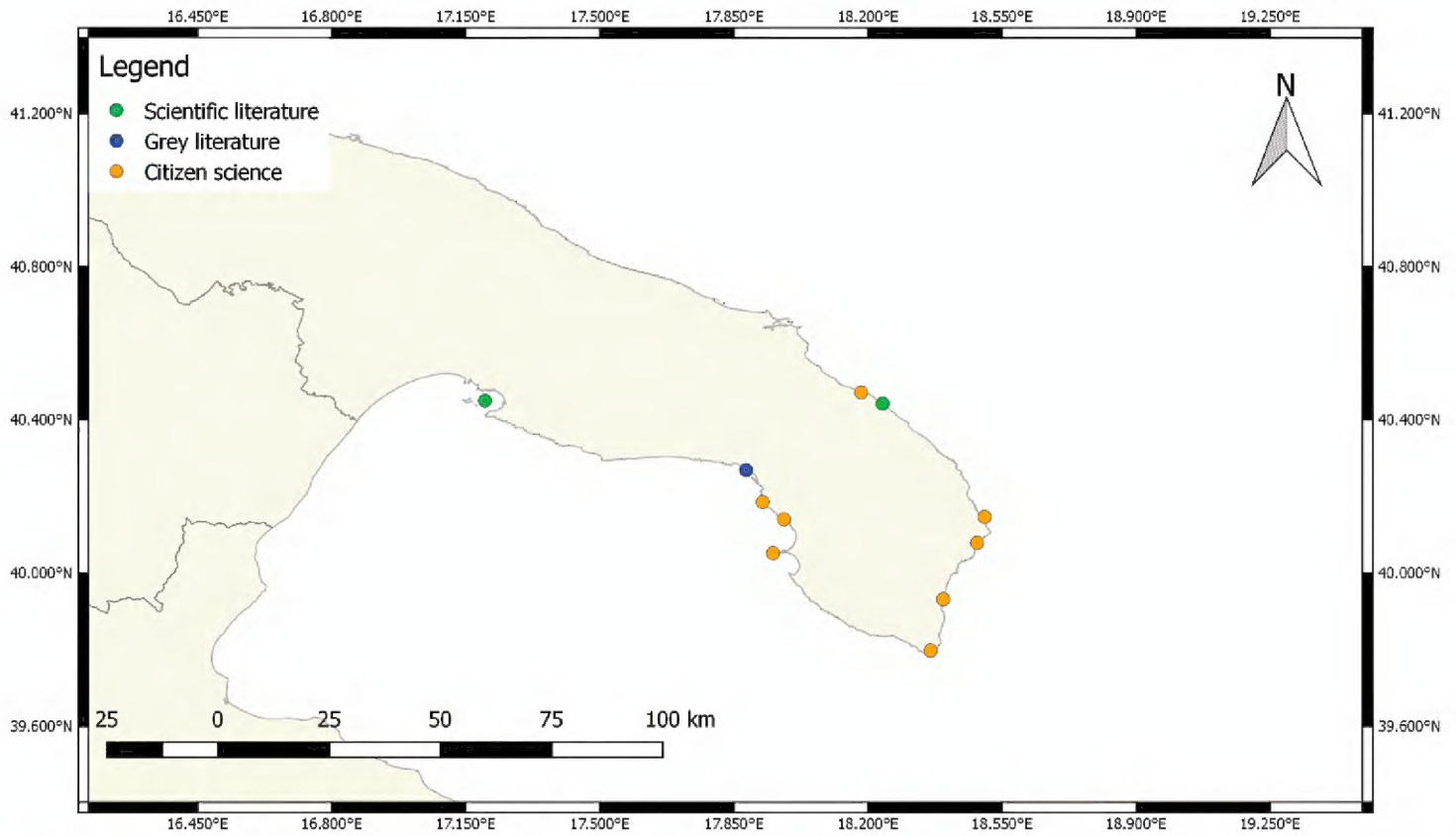


**Figure 4.** Map of *Pinna nobilis* distribution along the South Apulia coastline (Salento Peninsula) based on scientific literature, grey literature and citizen science data. In this area no NATURA 2000 Network Viewer geodata were recorded.

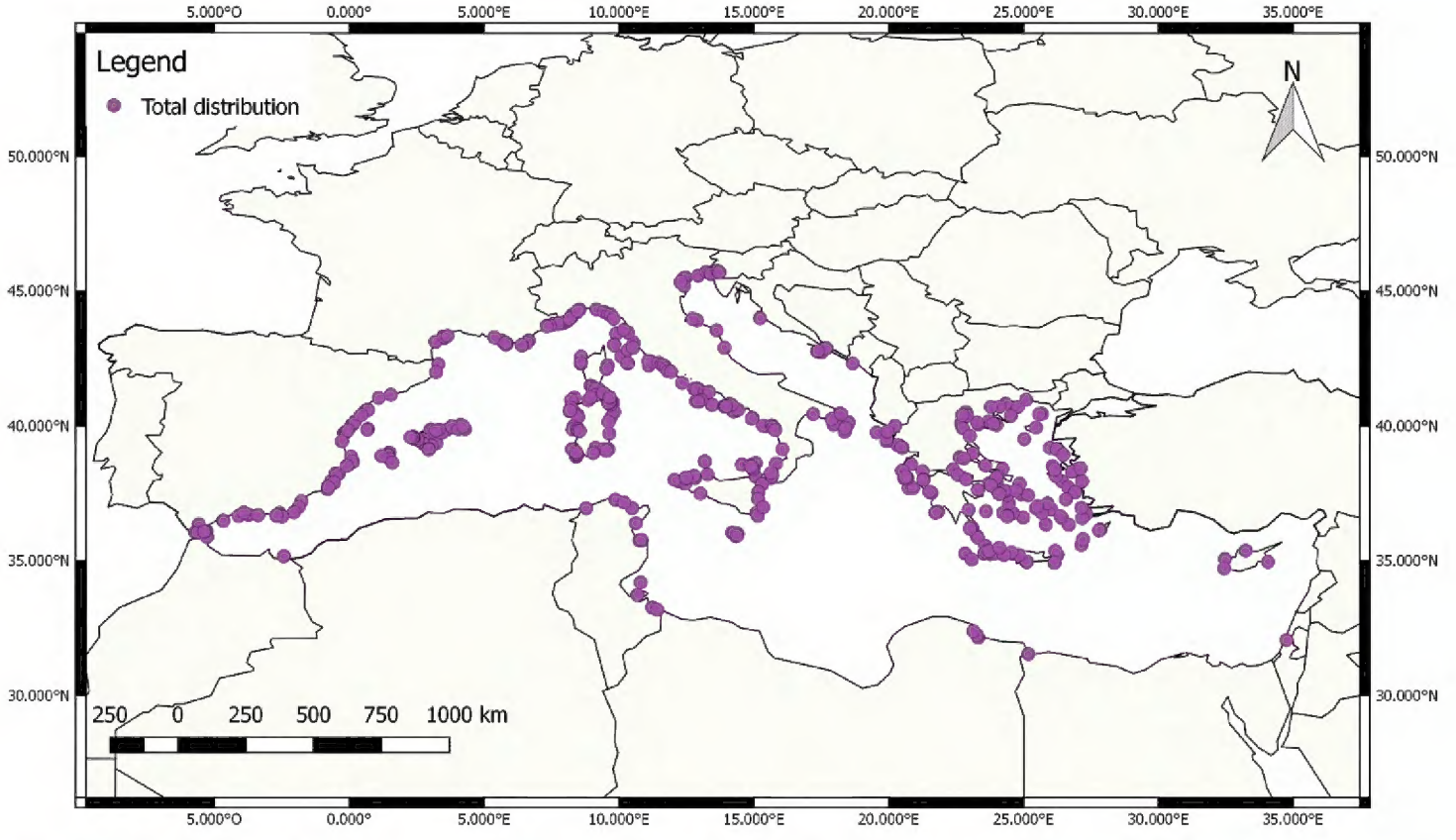


**Figure 5.** Map of *Pinna nobilis* distribution in the Mediterranean Sea obtained by combining all the points showed in the previous maps.

West area of the Mediterranean Sea, showing a higher concentration along the latitudinal gradient (Fig. 1). The implementation of a second mapping level including also 398 records of the NATURA 2000 Network Viewer is shown in figure 2. Since the

NATURA 2000 Network is employed officially in EU Countries, a wider distribution of *P. nobilis* at the Mediterranean Sea spatial scale can been observed along the coastline of EU Countries (Fig. 2). The overlapping of records has been considered only once. In the scaling down at the Italian coastline scale, 63 records of grey literature were integrated (Fig. 3), showing a further widening of *P. nobilis* distribution. Additionally, along the coasts of Campania and Lazio regions, a high presence of this species is reported in grey literature, but no results are found in scientific literature. In the region of Sardinia, the data from scientific literature are very scarce in comparison to those present in grey literature. Besides, in grey literature the presence of some individuals in the central area of Adriatic Sea has been observed.

Focusing on the Apulian Region, it can be noticed that scientific literature is limited only to the area of the Gulf of Taranto, but we found one record in grey literature related to the presence of the fan mussel in the Marine Protected Area of Porto Cesareo (Italy); furthermore, 8 new records were retrieved from citizen science (Fig. 4).

Gathering information obtained from the previous maps, figure 5 shows the total distribution of *P. nobilis* in the Mediterranean Sea, as a result of the integration and combination of four sources of data along with the decrease of the spatial scale.

## Discussions and conclusions

Presently, the conservation and management of the *P. nobilis* is an urgent challenge and more detailed maps of the species distribution are essential to investigate the habitat of the species, to identify available areas for restocking and to implement awareness campaigns to involve the general public and stakeholders. Furthermore, the aim of this work is to demonstrate that, in order to obtain a clear and complete *P. nobilis* distribution framework, it is necessary to integrate all the data and information available in relation to the spatial scale identified. We can certainly affirm, however, that through the integration of NATURA 2000 Network Viewer, grey literature and citizen science data, the resulting distribution of *P. nobilis* is wider compared to the measurements based only on scientific literature.

This work allowed the collection of datasets on the distribution of *P. nobilis* in the Mediterranean Sea, which can be a useful basis either for further studies in the waters of the Basin and for a time-space comparison of the same populations in order to monitor their status. The map (Fig. 1) built using the data collected from scientific literature made us conclude that the distribution of *P. nobilis* is concentrated in the Northern area of the Sea (except for the Tunisian coast). Nevertheless, we cannot identify whether the species is actually present in the southern Mediterranean Sea or if research efforts have been concentrated only in certain areas. This debate is open, since in this work we have been dealing with the implementation of the NATURA 2000 Network focusing on the Italian and Apulian coasts, including data from grey literature and citizen science. This approach shows a completely different scenario of the distribution of *P. nobilis*. Particularly, the distribution of data available in the NATURA 2000 Network allowed an extraordinarily accurate and updated knowledge of the species (Fig. 2).

Unfortunately, considering the NATURA 2000 Network has been commissioned by the European Union, it does not include data from non-European Countries bordering the Mediterranean Sea. The data on the bivalve distribution available in scientific literature are scarce for the Mediterranean basin, especially along the Italian coastline (Fig. 3) if compared to the apparent distribution range reported in grey literature. In Italy, the presence of the mollusk (considering only scientific literature) is limited exclusively to the coasts of Sardinia and Sicily, the Gulf of Trieste and the Venice Lagoon, the Tuscan Archipelago, the Liguria Sea and the Gulf of Taranto. By integrating data from scientific literature with those from grey literature and NATURA 2000 Network, a new map reveals a huge gap in scientific literature regarding this species distribution. Furthermore, in this work we focused on the presence of this species along the Apulian coastline. This choice was determined by the purpose of integrating the abovementioned literature with observations reported by scuba divers, fishermen and other people, which were obviously easier to be found in our region. Along the Apulian coastline (Fig. 4), the presence of *P. nobilis* in scientific literature is only reported in the Gulf of Taranto and, more recently, in the NATURA 2000 site of Aquatina di Frigole (Pinna et al. 2018). If we add citizen science to these records, we notice clearly that the species is present in many other areas of Salento sub-peninsula, like in Otranto, Porto Badisco, Santa Maria di Leuca, Gallipoli, Santa Caterina di Nardò, Tricase Porto, Torre Inserraglio and Regional Nature Park Bosco e Paludi di Rauccio. Combining all data coming from all types of records, we notice (Fig. 5) how the *P. nobilis* distribution is actually wider than has been reported exclusively in scientific literature. This discrepancy demonstrates that the information about the species distribution is not yet wholly available. In order to fill these information gaps and to enhance monitoring, it is necessary to integrate citizen science from all the states bordering the Mediterranean Sea to our current literature data. The study of some ecological or natural phenomena, such as species' geographic distribution or abundance of populations, requires a huge quantity of data and extensive sampling efforts. Usually, the support of volunteers proves to be decisive for the success or even for the feasibility of this type of studies. At the Mediterranean Sea scale, citizen science requires a structured framework, the identification of groups of interest and a focused training. The amount of data that can be obtained through public participation highly exceeds the investigations of a few researchers, making it possible to obtain results on a wider spatial and temporal scale. The result is the creation of a "bridge" between scientists, the academic world and the general audience, fundamental for scientific research to step forward and to become also able to exploit the potential of the web and social media. Additionally, citizen science creates participation and knowledge sharing, bringing society closer to science. The sensitization of the surrounding population shows itself an added value when it comes to conserving a protected species. Furthermore, over the last few years, this species has also been threatened by a parasite from the genus *Haplosporidium* that has affected all populations along the Spanish coast (with >80% mortality) and several other areas in France (Corsica) and Italy (Sicily, Apulia and Campania) (Vázquez-Luis et al.

2017b, IUCN 2018). For this reason, mapping at different spatial scales can be useful to carry out research, monitoring and conservation actions, e.g. the implementation of species conservation by captive breeding programs for the future restocking of resistant juveniles may be one of these. Therefore, it is important to complete the culture of the conservation of *P. nobilis* (Dégremont et al. 2015). The restocking could be concentrated into dense patches, higher rates of successful fertilization are probable, thus the positive impact of transplantation actions on fan mussel populations could be great due to higher fertilization and increased recruitment (Katsanevakis 2016). To do this, we need to have a detailed knowledge about *P. nobilis* distribution in the Mediterranean basin; furthermore, it is important that not only research efforts are made, but also the media and public should participate in learning about, and protecting, this species.

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